Theoretical Approach in Reducing Total Network Power Consumption by Utilizing 5G Technologies

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Abstract

We expect future 5G network to have low power consumption and minimal delay, as well as a more flexible and secure architecture. Most of the research is concerned primarily with increasing energy efficiency and decreasing latency. Implementation of Software Defined Mobile Networking (SDMN) to control the range of cell site communication and device-to-device (D2D) technologies to enable the devices on the network to behave as routers between other devices and the cell site has the potential to significantly reduce the overall power consumption in the mobile network. Our research provides a theoretical approach for such model and shows that its implementation will increase energy efficiency in 5G.

Motivation

We propose a model to reduce the total power consumption in a 5G network. The main motivation behind our model is as follows. First, the power required to transmit information over a certain distance is proportional to the square of that distance. This means that the longer the range of transmission is, the power required to transmit increases significantly. Moreover, if we assume that 1) D2D technologies [1] are capable of not only establishing a direct communication between two devices but also allow a device in the network to act as a router, 2) that a secure and reliable protocol exists for a device in the network to route information between the cell site and another device, and 3) a cell site can utilize SDMN technologies [2] to adjust the range of transmission, then power consumption can be reduced significantly for all devices in the network and the cell site by substituting longer range communication between two devices with an intermediate, router device.

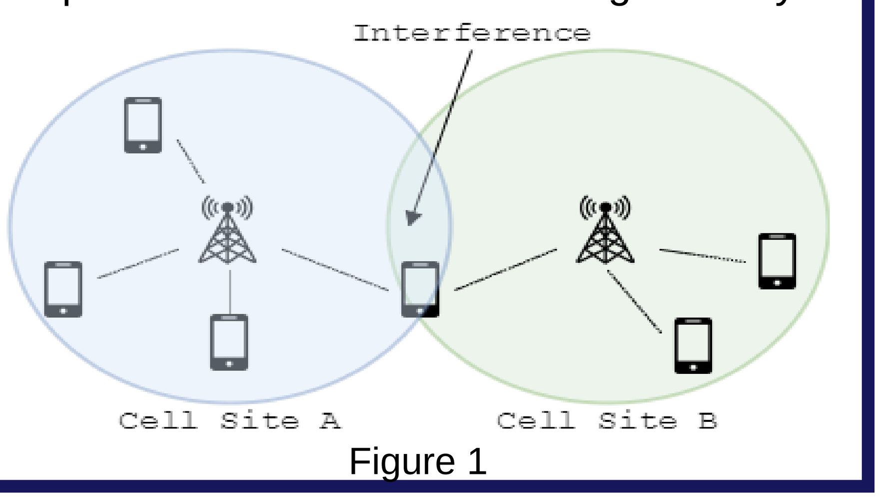

Figure 1

Methodology

Assumptions

- One ideal cell site with N devices in maximum communication range
- Some devices in network can be idle or active
- SDMN allows cell site to dynamically adjust the communication range
- All devices are capable of D2D and are enabled as routers via secure and reliable protocol
- All devices outside of the current communication range are aware of closest forwarding devices within communication range
- All variables in the model except device location and number of active devices are constant
- All communication is one way transmission of packet of constant length
- Maximum hop count in the network is one
- Power consumed by router device to forward the packet is ignored
- All devices have static location for the purpose of simulation

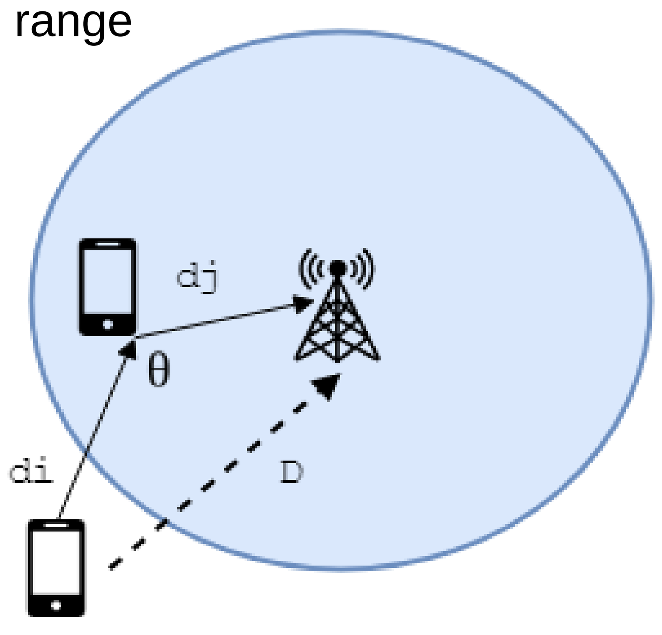

Figure 2

Model Formulation

The power required to transmit a bit of data over range *D* (Friis Equation):

$$P_T \propto D^2$$

The power required to transmit between a device and cell site:

$$P_{\text{device}\rightarrow tower} = D^2$$

The power required to transmit from originating device to the cell site using a routing device:

$$P_{\text{device}\rightarrow forwarder} + P_{\text{forwarder}\rightarrow tower} = d_i^{\,2} + d_j^{\,2}$$

Power difference between the standard model, where each device communicates directly with the cell site and our model, where device communication may utilize a router device:

$$\Delta P = P_{\text{device}\rightarrow tower} - \left(P_{\text{device}\rightarrow forwarder} + P_{\text{forwarder}\rightarrow tower}\right)$$
$$= D^2 - \left(d_i^{\,2} + d_j^{\,2}\right)$$

The communication range in standard model expressed as communication range using a router device in our model (law of cosines):

$$D^2 = \mathrm{d}_\mathrm{i}^2 + d_j^{\,2} - 2 \cdot d_i d_j \cos(\theta)$$

The power consumption difference between standard model and our model:

$$\Delta P = d_i^{\,2} + d_j^{\,2} - 2 \cdot d_i d_j\, cos(\theta) - \left(d_i^{\,2} + d_j^{\,2}\right)$$
$$\Delta P = -2 \cdot d_i d_j \cos(\theta)$$

Analysis

Our model performs better than the standard model when power consumption difference is positive. ΔP is positive when $90° < \theta \le 180°$ and has the greatest magnitude when d_i and d_j are about equal.

We expect the simulation results to reflect that on average, our model saves power since on average, the network will reflect such properties.

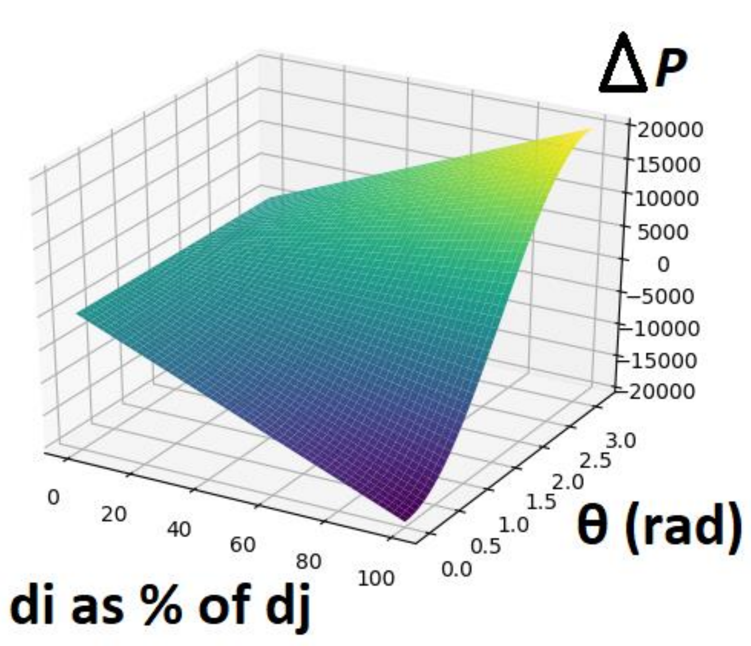

Figure 3

Simulation Results and Discussion

Simulation

Python 3.5 was used to generate the model simulation. The model featured a 200x200 unit space with cell site in the center. 100 devices were placed into the maximum communication range of 100 units within the cell site, randomly. The device distribution was uniform for the first experiment and varied for second experiment. A single communication burst featured one bit transmission between an active device in the network and the cell site. Active devices were randomized. Communication range was varied and devices outside of the range used a forwarding device within the range (active or idle) to communicate with the tower.

Power was calculated per model formulation (proportional to the square of signal travel distance). In simulations, R represents the tower communication range and N represents the number of active devices. Figure 4 shows sample simulation output.

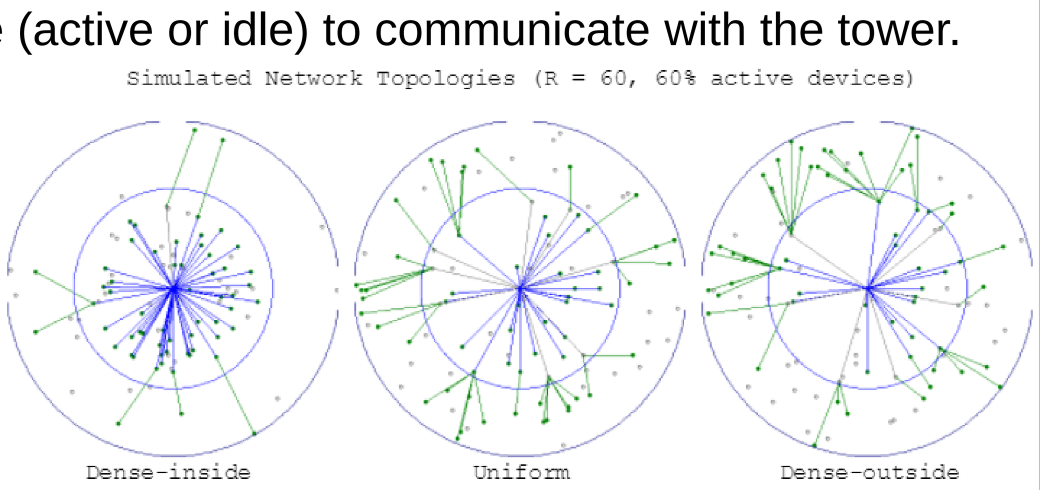

Figure 4

Uniform Network: ΔP vs. % Active Devices

Figure 5 shows simulation results. *Results show that **R = 50** reduces power consumption of the network by **39% - 44%**, dependent of the number of active devices. **R_{max}** and **R = 10** yield the most power consumption in the network.*

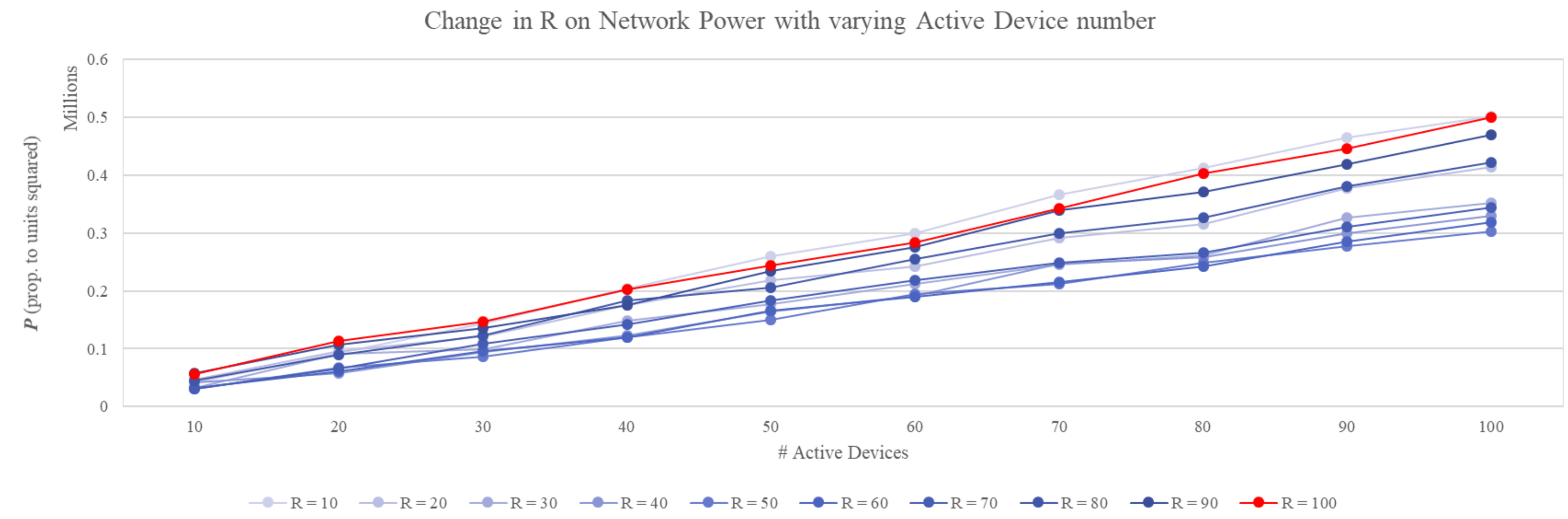

Figure 5

ΔP in Various Network Topologies

Figure 6 shows simulation results for different network topologies:

- Uniform – the device locations were placed with uniform random distribution,
- Dense-inside – 80% of devices were placed within *R = 50,*
- Dense-outside – 80% of devices were placed outside of *R = 50*

*Results show that in Uniform and Dense-Outside topologies, power is reduced if **R = 60** for any number of active devices. In the Dense-inside network, power reduction is achieved when **R = 20** for **N** greater than **60** but shows that **R = 60** is better when **N = 20**.*

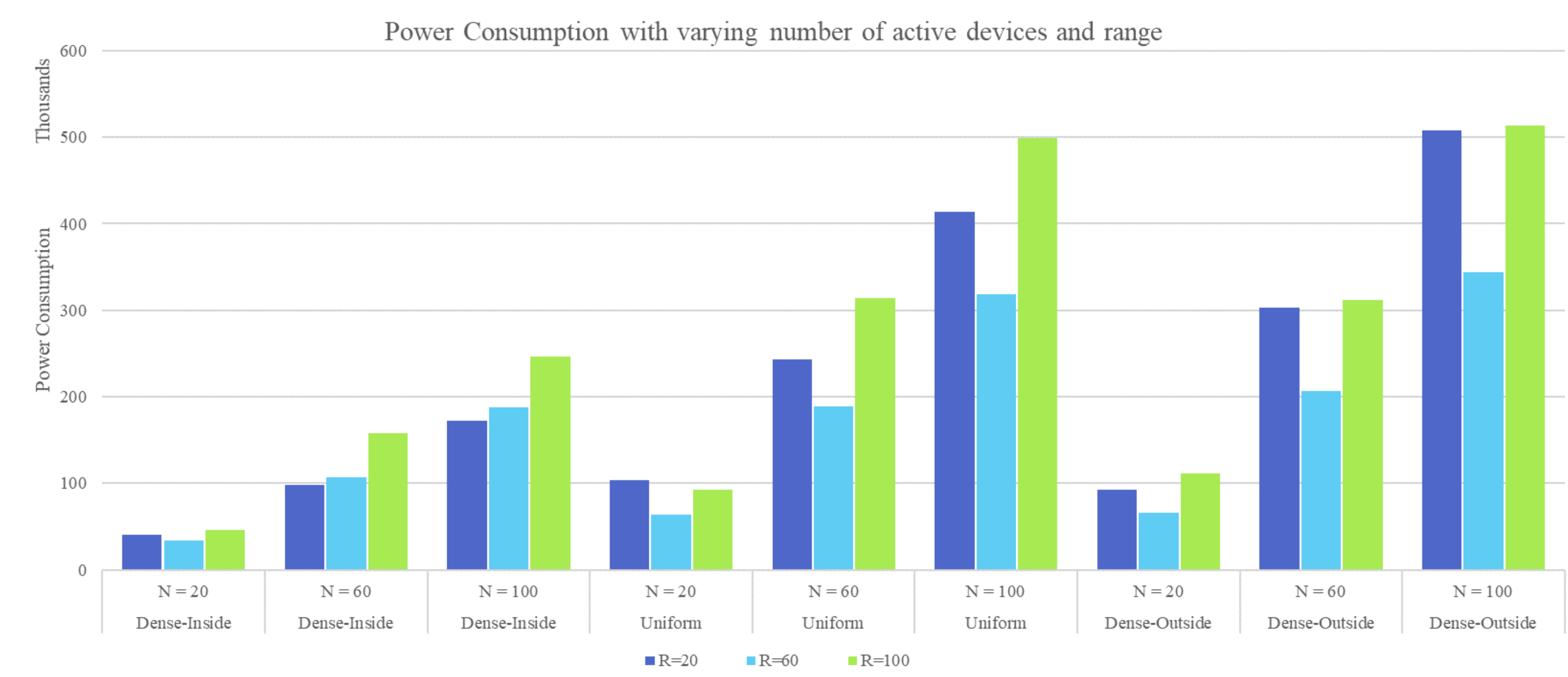

Figure 6

References

[1] Iliev, T., et al. Power control schemes for device-to-device communications in 5G mobile network. In Information and Communication Technology, Electronics and Microelectronics (MIPRO), 2017 40th International Convention on. 2017. IEEE.

[2] Chen, T., et al., Software defined mobile networks: concept, survey, and research directions. IEEE Communications Magazine, 2015. 53(11): p. 126-133.